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(51) INT CL[7]
G02B 6/34 6/12, H04J 14/02

(52) UK CL (Edition S)
H4B BN

(56) Documents Cited by ISA
EP 0814629 A DE 019647789 A JP 090061649 A
MIZUOCHI:JOURNAL LIGHTWAVE TECHNOLOGY VOL.16,NO.2 1/2/98 PP265-276 CULLEN:ELECTRONIC LETTERS VOL.30,NO.25 8/12/94 PP2160-2162 ROURKE:ECOC '96,VOL3,15-19/9/96 PP151-154 KASHYAP:IEEE PHOTONICS TECHNOLOGY LETTERS VOL.5,NO.2 1/2/93 PP191-194 CHEUNG:COMMUNICATIONS:CONNECTING THE FUTURE,SAN DIEGO,DEC2-5 1990 VOL.3 2/12/90

(58) Field of Search by ISA
INT CL[7] **G02B, H04J**

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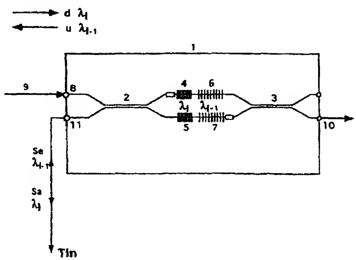
(54) Abstract Title
Wavelength router for optical bidirectional transmission of data

(57) A wavelength router for optical bidirectional transmission of data, containing a plurality of add/drop filters (1) for signal injection to form a wavelength multiplex and for selective extraction of signals in order to break said multiplex down. A wavelength router of this kind represents a considerable amount of complexity in terms of circuitry; especially since only one respective signal of a subscriber can be injected or extracted using an add/drop filter. The aim of the invention is to reduce overall circuit complexity in said wavelength router. Injection and extraction are carried out respectively in the same add/drop filter (1) for a subscriber. In order to avoid crosstalk, extraction occurs at a wavelength of λ_j and injection occurs at a down-shifted wavelength λ_j. Preferably, the wavelength difference between injection and extraction corresponds to a wavelength distance of the wavelength multiplex.



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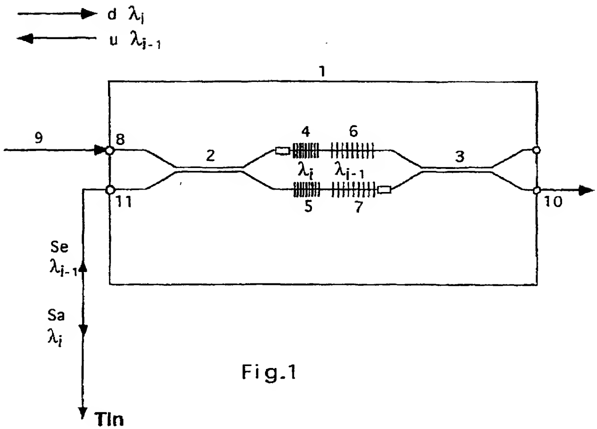

d λ_i
u λ_{i-1}
1
9
8
2
4
6
3
λ_i
λ_{i-1}
11
5
7
10
Se
λ_{i-1}
Sa
λ_i
Tln

Fig.1

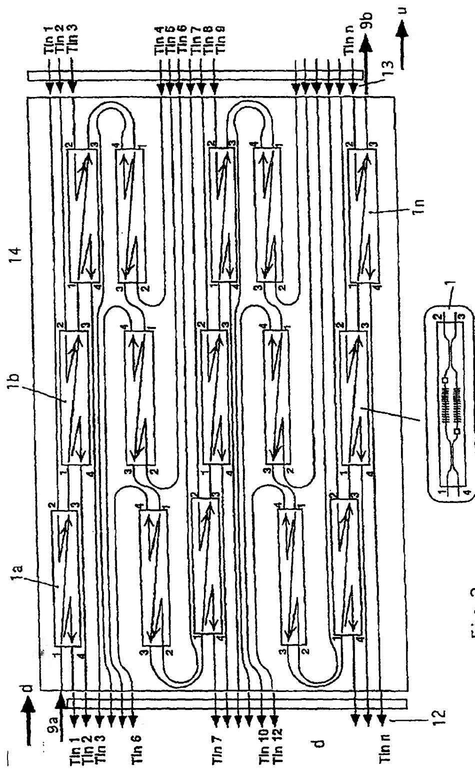

Tln 1
Tln 2
Tln 3
Tln 4
Tln 5
Tln 6
Tln 7
Tln 8
Tln 9
Tln n
9b
u
13
14
1b
1a
1n
1
d
9a
Tln 6
Tln 7
Tln 10
Tln 12
12

Fig.2

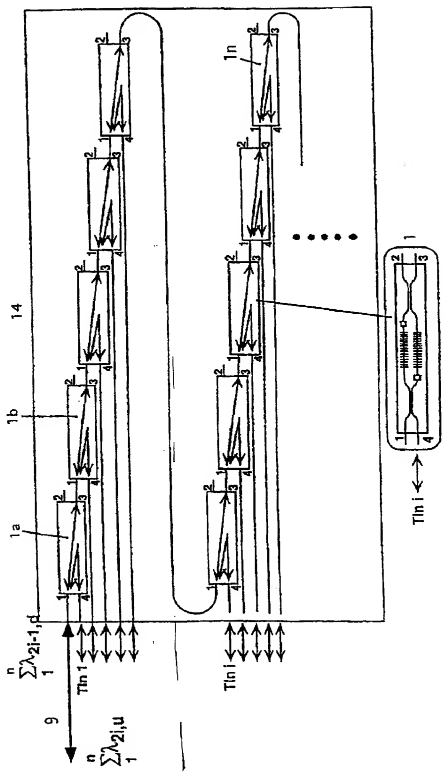

14
1a
1b
1n
1
2
3
4
9
Tln 1
Tln i
$\sum_{1}^{n}\lambda_{2i-1,d}$
$\sum_{1}^{n}\lambda_{2i,u}$
$\lambda_{2i-1,d}$ $\lambda_{2i,u}$

Fig.3

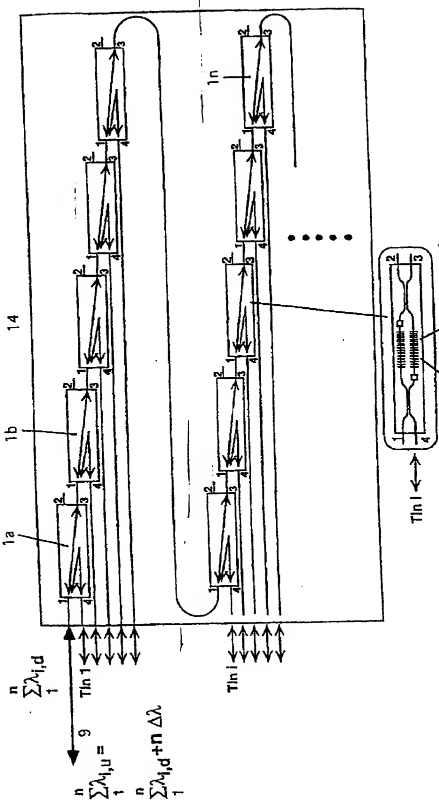
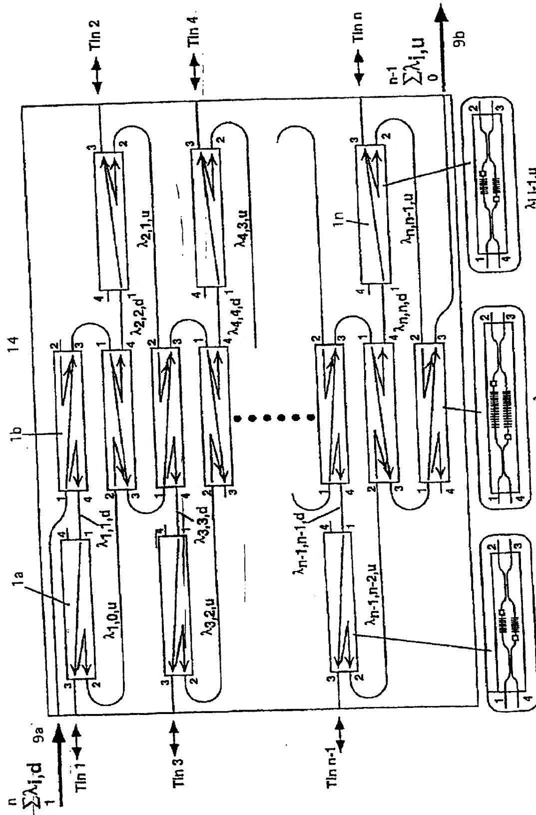


Fig.4


14
1a
1b
1n
9a
9b
Tln 1
Tln 2
Tln 3
Tln 4
Tln n-1
Tln n
$\sum_{1}^{n}\lambda_{i,d}$
$\sum_{0}^{n-1}\lambda_{i,u}$
$\lambda_{1,0,u}$
$\lambda_{1,1,d}$
$\lambda_{2,1,u}$
$\lambda_{2,2,d}$
$\lambda_{3,2,u}$
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$\lambda_{n-1,n-1,d}$
$\lambda_{n,n-1,u}$
$\lambda_{n,n,d}$
$\lambda_{i,i-1,u}$
$\lambda_{i,i,d}$
$\lambda_{i,i-1,u}$
$\lambda_{i,i-1,u}$

Fig.5

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Wavelength Router for an Optical Bidirectional Data Transfer

Prior art

The invention is based on a generic type as described in the independent Patent Claim 1.

A subscriber connection network for a data transfer of this type contains what is referred to as a terminal exchange, also known as a CO (Central Office). Arranged in this are a plurality of transceivers, which are allocated to the individual subscribers and which operate at different optical wavelengths, and which are connected to the inputs of a wavelength router. This delivers a wavelength multiplex at the output, which is conducted to the input of a transmission line. The output of the transmission line is connected to the input of a second wavelength router arranged in a cable distributor arranged in a second wavelength router, which breaks the transferred wavelength multiplex down again into the individual wavelengths for the subscriber connection lines which follow. The subscriber connection lines are in turn connected to the transceivers allocated to the individual subscribers. The direction of transfer from the terminal exchange to the cable distributor is designated in general as the downstream direction, while the opposite direction, from the subscribers to the terminal exchange, is designated as the upstream direction.

The coupling-in of the signal from a subscriber in order to form the wavelength multiplex, and the decoupling of the signal from the wavelength multiplex for it to be broken down into the individual wavelengths for the separated subscriber lines is effected in a coupling/ decoupling filter, which in general and in the following description is designated as an add/drop filter. A filter of this nature contains two 3 dB couplers, between which is located a reflection grating, in particular what is known as a UV-induced Bragg grating, which is tuned to the wavelength of the coupled-in or decoupled signal. In the cable distributor, for example, the decoupling of the signal for a subscriber is carried

out in the add/drop filter, fed from the transmission line, in that the signal received is reflected in full with a specific wavelength to the Bragg grating, and can be drawn off at a connection of the 3 dB coupler. The other wavelength multiplex signal, without the decoupled signal, runs through the add/ drop filter, and is conducted from the connection of this filter to the next add/drop filter, for the decoupling of the signal with another wavelength for the next subscriber. The decoupling of a signal for a subscriber to form the wavelength multiplex is effected by the signal being conducted to the 3 dB coupler of the add/drop filter. The signal is reflected completely in the Bragg grating, and is therefore inserted into the wavelength multiplex running in the upstream direction via the add/drop filter and the transmission line.

From the prior art, wavelength routers are known which consist of a series circuit of four drop/add filters (A.N. Rourke et al., "A low loss 4-channel wavelength demultiplexer based on fibre Bragg gratings", Proc. ECOC'96, WeD.1.7, 3.15 ff.), manufactured in fibre technology. It is also known that this arrangement can be realised in a PLC (Planar Lightwave Circuit) technology (G.E. Kohnke et al., "Planar waveguide Mach-Zender bandpass filter fabricated with single exposure UV-induced gratings", Proc. OFC'96, ThQ6, pp. 277 ff.).

The wavelength router with a plurality of add/drop filters connected in series represents a considerable investment in circuitry, especially since in each case only the signal with a wavelength for one subscriber can be decoupled or coupled in with one add/drop filter.

The objective on which the invention is based is the reduction of the overall circuit investment for the add/drop filter in the wavelength router. This objective is achieved by the invention described in Claim 1.

Advantages of the invention

The invention achieves the purpose that the coupling and decoupling of the signal can be effected in the same add/drop filter, i.e. the filter can be used for a double purpose, without

interference or cross-talk occurring between the signals. The displacement of the wavelength between coupling-in and decoupling does to a certain extent decouple these two processes. The transceivers located in the subscriber lines are adjusted selectively to a wavelength in such a way that no interference from an adjacent wavelength can arise. If the same wavelength were to be used in an add/drop filter for the coupled-in signal and the decoupled signal, tolerances in the components would then lead to temperature changes, insertion losses, and similar unacceptable interference and cross-talk.

Advantageous embodiments of the invention are described in the dependent Claims.

Drawings

A number of embodiments of the invention are represented in the drawings and explained in the following description. The drawings show:

Figure 1: An add/drop filter designed and operated in accordance with the invention;

Figure 2: A wavelength router with a plurality of add/drop filters of this nature, connected in series, and a bidirectional transmission over two separate fibres;

Figure 3: A wavelength router with decoupling and coupling of the signals from and into the add/drop grating[1], which deviates from that shown in Figure 2, and a bidirectional transmission via only one fibre;

Figure 4: A variation from Figure 3, in which the wavelengths for the two directions are not interlocked, and

Figure 5: A combination of the embodiment with only one subscriber connection line for each subscriber Tln, and with transmission over two fibres for both the directions.

The symbols used in the description and in the drawings have the following significance:

For "downstream" = from the terminal exchange in the direction towards the subscriber;

[1] *We believe this should read ' add/drop filter'*

Index of the individual subscriber and the associated wavelength λ

For "upstream" = from the subscriber in the direction towards the terminal exchange

λ wavelength of the optical signal

Wavelength of the signal decoupled from an add/drop filter

λ_{i-1} wavelength of the signal coupled into an add/drop filter.

In Figure 1, an add/drop filter 1 contains a first 3 dB coupler 2, a second 3 dB coupler 3, two 3 dB couplers 3, two Bragg gratings 4, 5, tuned to a wavelength λ_i, and two Bragg gratings 6, 7, tuned to a wavelength λ_{i-1}, which all have the effect of creating a complete reflection of the signals with the wavelengths λ_i and λ_{i-1} respectively. The connection 8 of the filter 1 is connected to the output of a transmission line 9 coming from the terminal exchange, and the connection 10 is connected to the input of a following add/drop filter for another wavelength. A connection 11 of the filter 1 serves to couple in (add) a signal Se with the wavelength λ_{i-1} and to decouple (drop) a signal Sa with the wavelength λ_i. An add/drop filter is located, for example, in a wavelength router in the cable distributor, and serves to couple in the signal from a subscriber with a specific wavelength into the wavelength multiplex transferred via the line 9 to the terminal exchange, and to decouple from the wavelength multiplex coming via the line 9 the signal for a subscriber, in a frequency-selective manner.

The manner of effect of this filter is as follows:

The decoupled signal Se with the wavelength λ_{i-1} is conducted to the connection 11, passes via the 3 dB coupler 2 to the Bragg gratings 6, 7, and is reflected by them completely in the upstream direction u. Accordingly, it is already conducted into the add/drop filter which follows the connection 10, and is inserted via the line 9 into the wavelength multiplex being carried in the upstream direction u. The signal Sa with the wavelength λ_i received and decoupled in the wavelength multiplex from the line 9 is reflected in this in its entirety to the Bragg gratings 4, 5, passes via the 3 dB coupler 2 to the connection 11, and can be conducted from there to the corresponding transceiver for the

subscriber with a wavelength λ_i.

It can be appreciated that the signals Se and Sa processed simultaneously in the add/drop filter 1 have different wavelengths in each case, and that interference between these signals, for example in the form of cross-talk, will be avoided. The difference between the wavelengths λ_i and λ_{i-1} corresponds for preference to a wavelength interval of the wavelength multiplex. The wavelengths λ_i on the one hand and λ_{i-1} on the other, are for preference intermeshed or interlocked with one another in the wavelength axis. It is also possible, however, that all wavelengths λ_i for the decoupling are located in a first wavelength range and all wavelengths for the coupling-in lie in a second wavelength range, adjacent to the first in the frequency axis.

The coupling and decoupling of the signal does not necessarily take place at the same connection of the add/drop filter, as shown in Figure 1. It is also possible that the coupling of the signal from a subscriber will be effected into the wavelength multiplex at the right-hand end of the add/drop filter via the 3 dB coupler 3. Instead of the two reflection filters 4, 5 or 6, 7 respectively, tuned to different wavelengths λ_i and λ_{i-1}, it is also possible in each case for a wideband reflection filter to be used, the band width of which extends in each case over the wavelengths λ_i and λ_{i-1}.

Figure 2 shows a wavelength router 14 with a plurality of add/drop filters 1, located in series. The wavelength multiplex coming from the line or fibre 9a is conducted to the first add/drop filter 1a, where the signal with the wavelength λ_i for the subscriber Tln 1 is decoupled in the manner described. The wavelength multiplex running through the add/drop filter 1a without the decoupled signal for Tln 1 then passes to the next add/drop filter 1b, where in the same manner the signal with the wavelength λ_2 for the subscriber Tln 2 is decoupled. In this manner, the signals with the wavelengths λ_1 - λ_n for the subscribers Tln 1 to Tln n, in n add/drop filters 1a to 1n, are output one after another on separate lines 12, and conducted to the selective transceivers in each case for the individual subscribers Tln 1 - Tln n. As a departure from Figure 1, in

Figure 2 the decoupling and coupling-in of the signal are effected at different connections of the add/drop filter, for example at the filter 1a at the connections No. 4 and No. 2.

In addition to this, the outgoing connection lines 13 from the subscribers Tln 1 to Tln n are coupled in at the inputs of the wavelength router 14 to the individual add/drop filters 1a-1n, where the selective signals are coupled-in in the manner described, and create the wavelength multiplex for the transfer via the line 9b in the upstream direction u. The transfers in the downstream (drop) direction d and in the upstream (add) direction u are accordingly effected in Figure 2 via separate fibres 9a and 9b, whereby the wavelength multiplex for the transfer in the upstream direction u emerges at the output (No. 3) of the last add/drop filter 1n. The transfer in the downstream direction d is effected according to Figure 1 at the wavelengths λ_i and the transfer in the upstream direction u at the wavelengths λ_{i-1}.

With each of the individual add/drop filters 1a to 1n, the wavelength of the decoupled signal Sa again amounts to λ_i, while that of the coupled-in signal Se amounts to λ_{i-1}, whereby the wavelength difference between λ_i and λ_{i-1} is for preference equal to a wavelength interval of the wavelength multiplex. As a result of this wavelength displacement between the decoupled signals for the transfer in the downstream direction d and the coupled-in signals for the transfer in the upstream direction u at each add/drop filter 1a-1n, interference and cross-talk between these signals is avoided.

In Figure 3, the transfer in the upstream direction u and the downstream direction d, by contrast with Figure 2, is effected via a common line or fibre 9, whereby, as in Figure 1, the coupling and decoupling is effected at the same connection (terminal 4) of each add/drop filter 1. The bandwidth of the reflection filter extends over the two adjacent wavelengths λ_i and λ_{i-1}, in which situation the wavelengths λ_i for the downstream direction and λ_{i-1} for the upstream direction are intermeshed or interlocked with one another.

Figure 4 shows an embodiment in which the wavelengths λ_i for the downstream direction d and λ_{i-1} for the upstream direction u are not intermeshed or interlocked, but the wavelength ranges for

both directions are juxtaposed with one another; i.e. they follow one another in the frequency axis. In each add/drop filter 1, decoupling takes place at the wavelength $\lambda_i+n\ \lambda$. The bidirectional transfer is again effected via one single fibre 9.

In Figure 5 the wavelength multiplex is fed in from the line or fibre 9a in the downstream direction d into the wavelength router 14. The add/drop filters 1a to 1n are arranged in column fashion in the centre and connected to one another in meander-fashion. With the first add/drop filter 1a, no coupling-in is provided for, and no decoupling with the last add/drop filter 1n. Each subscriber T1n is connected via a line for decoupling and coupling to the wavelength router 14. The transfer for the two directions is effected via two separate fibres 9a and 9b.

Claims

1. Wavelength router for an optical bidirectional data transfer by means of a wavelength multiplex with a series circuit of coupling/decoupling filters (1), whereby the incoming signal for a subscriber is frequency-selectively decoupled in the filters, and the outgoing signal from a subscriber is frequency-selectively coupled in, characterised in that the decoupling and coupling are effected in each case for a subscriber (Tln) in the same coupling/decoupling filter (1), and in the filter (1) the decoupling is effected at a wavelength λ_i and the coupling-in at a wavelength λ_{i-1}, which is displaced downwards by one wavelength difference of at least one wavelength interval of the wavelength multiplex.

2. Wavelength router according to Claim 1, characterised in that the coupling/decoupling (add/drop) filter (1) features two reflection gratings (4, 6; 5, 7) connected in series, one of which is tuned to the wavelength λ_i and the other to the wavelength λ_{i-1}.

3. Wavelength router according to Claim 1, characterised in that the coupling/decoupling (add/drop) filter (1) contains in each case a reflection grating with a band width which extends over the decoupling wavelength λ_i and the coupling-in wavelength λ_{i-1} in this filter.

4. Wavelength router according to Claim 1, characterised in that the wavelength difference corresponds to a wavelength interval of the wavelength multiplex.

5. Wavelength router according to Claim 1, characterised in that the wavelengths λ_i for decoupling, and the wavelengths λ_{i-1} for coupling, are intermeshed or interlocked with one another for coupling into the wavelength axis.

6. Wavelength router according to Claim 1, characterised in that all the wavelengths λ_i for decoupling lie in a first wavelength range, and all wavelengths λ_{i-1} for coupling-in lie in a second wavelength range, located adjacent to the first in the frequency axis.

7. Wavelength router according to Claim 1, characterised in that the bidirectional data transfer is effected via a common fibre (9).

INTERNATIONAL SEARCH REPORT

International Application No
PCT/DE 99/01488

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02B6/34 G02B6/12 H04J14/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G02B H04J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 09 061649 A (KOKUSAI DENSHIN DENWA CO LTD < KDD&GT) 7 March 1997 (1997-03-07) figures 1-4 ---	1-6,8 7
A	DE 196 47 789 A (ALSTHOM CGE ALCATEL) 20 May 1998 (1998-05-20) abstract column 5, line 61 -column 6, line 10 --- -/--	1

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 November 1999	18/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chauvet, C

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Form PCT/ISA/210 (second sheet) (July 1992)

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	MIZUOCHI T ET AL: "INTERFEROMETRIC CROSSTALK-FREE OPTICAL ADD/DROP MULTIPLEXER USING MACH-ZEHNDER-BASED FIBER GRATINGS" JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. 16, no. 2, 1 February 1998 (1998-02-01), pages 265-276, XP000750668 ISSN: 0733-8724 page 265, column 1 -column 2, line 12 page 266, column 1, line 18 -column 2, line 6 ---	1
A	CULLEN T J ET AL: "COMPACT ALL-FIBRE WAVELENGHT DROP AND INSERT FILTER" ELECTRONICS LETTERS, vol. 30, no. 25, 8 December 1994 (1994-12-08), pages 2160-2162, XP000502111 ISSN: 0013-5194 page 2160 -page 2161, column 1, line 13 ---	1
A	ROURKE H N: "A LOW LOSS 4-CHANNEL WAVELENGTH DEMULTIPLEXER BASED ON BIBRE BRAGG GRATINGS" ECOC'96, vol. 3, 15 - 19 September 1996, pages 151-154, XP002118836 OSLO, NORWAY cited in the application page 3.151 -page 3.152, line 18 ---	1
A	EP 0 814 629 A (LUCENT TECHNOLOGIES INC) 29 December 1997 (1997-12-29) abstract column 8, line 20 - line 52 ---	1
A	KASHYAP R ET AL: "LASER-TRIMMED FOUR-PORT BANDPASS FILTER FABRICATED IN SINGLE-MODE PHOTOSENSITIVE GE-DOPED PLANAR WAVEGUIDE" IEEE PHOTONICS TECHNOLOGY LETTERS, vol. 5, no. 2, 1 February 1993 (1993-02-01), pages 191-194, XP000362867 ISSN: 1041-1135 page 191 -page 192, column 2, line 2 ---	1

-/--

1

International Application No
PC./DE 99/01488

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication where appropriate of the relevant passages	Relevant to claim No
A	CHEUNG K W: "WAVELENGTH-SELECTIVE CIRCUIT AND PACKET SWITCHING USING ACOUSTO- OPTIC TUNABLE FILTERS" COMMUNICATIONS: CONNECTING THE FUTURE, SAN DIEGO, DEC. 2 - 5, 1990, vol. 3, 2 December 1990 (1990-12-02), pages 1541-1547, XP000218834 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS ISBN: 0-87942-632-2 abstract page 1544, column 1, line 13 - line 14 -----	1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/DE 99/01488

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 09061649 A	07-03-1997	NONE	
DE 19647789 A	20-05-1998	EP 0921420 A	09-06-1999
		AU 4369497 A	21-05-1999
		JP 10153718 A	09-06-1998
		US 5940568 A	17-08-1999
EP 0814629 A	29-12-1997	US 5721796 A	24-02-1998
		JP 10062826 A	06-03-1998